Box 7-1. Maximum Sustained Yield

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The objective of maximum sustained yield (MSY) seems to capture the idea of sustainable development: to achieve as much as possible without compromising future capabilities. To illustrate the concept of MSY, consider the per capita growth rate of an exploited population. If the population is at its largest possible size (the carrying capacity of its environment), then the per capita growth rate is zero—births are exactly balanced by deaths. If the population is below carrying capacity, less competition for resources leads to a higher birth rate and a lower death rate, and hence the per capita growth rate is positive. The maximum per capita growth rate may be expected at the lowest population size, since the competition is least with a single breeding unit. The net growth rate is obtained by multiplying the per capita growth rate by the population size. The result is a curve that is zero at a population size equal to zero or the carrying capacity, but positive in between (Figure 7-1).

If the population is subject to harvesting, the harvesting rate must be subtracted from the net growth rate when considering the population dynamics. In the simplest case, the difference between the two rates will be positive between two population sizes labeled x_1 and x_2, and negative outside that interval (Figure 7-1). Hence the population increases between those values and decreases otherwise. If the harvest is constant, the population will move toward x_2 if it is above x_1; otherwise, it will decrease toward zero. If the harvest is set above the maximum of the net growth curve (labeled h_{MSY}), the population will decrease toward zero. Hence any harvesting rate below h_{MSY} is sustainable. The maximum of these sustainable rates is h_{MSY} itself. Note that "sustainability" has acquired a slightly different meaning in this context: the sustainability applies only if x never drops below x_1. If $h = h_{MSY}$, then $x_1 = x_2 = x_{MSY}$, and sustainability applies only if the population never drops below x_{MSY}.

There is a conflict between maximization and sustainability: the higher we set the harvest rate, the more fragile is the sustainability we seek to preserve. There is no margin for error if $h = h_{MSY}$ and $x = x_{MSY}$. If environmental variation should temporarily decrease the per capita growth rate, a policy based on the previously observed population growth rate may be unsustainable. If environmental variation should temporarily increase the net growth rate, our desire to

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maximize returns may lead us to set the harvest rate too high to be sustained over the longer term.

A policy of maximization of the sustained yield can succeed only if information about changing conditions is readily available, and if it is possible to make quick adjustments to changing conditions. However, for many natural populations it is difficult or impossible to monitor the actual population size, and it may also be difficult to monitor and control the harvest rate (and the rate of deaths that are not recorded as part of the harvest).

tinue the harvest even when it might jeopardize future harvests. Hilborn and Walters (1992) discuss such issues for developing fisheries, where the dynamics of the stock are unknown and must be determined as part of the optimization process. Their main conclusions are summarized in two principles: (1) one cannot determine the potential yield from a fish stock without overexploiting it; (2) the hardest thing to do in fisheries management is to reduce fishing pressure.

Clark (1990) describes another complication in stock dynamics: the per capita growth rate may decrease at low population sizes. This phenomenon of depensation is seen in diverse fish stocks (Lierman and Hilborn 1997). Possible causes of depensation include an inverse relationship between predation on the stock and stock size, perhaps related to schooling behavior of the stock or its predators (Walters and Korman 1999). Steele and Henderson

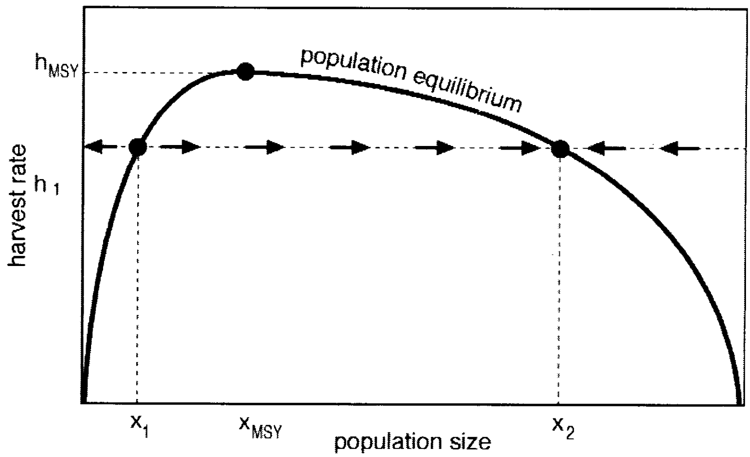

Figure 7-1. Rate of population growth or harvest versus population size for a fish stock. The harvest rate at maximum sustained yield is h_{MSY}. The horizontal line shows a harvest rate $h < h_{MSY}$, for which there are two equilibria, x_1 and x_2.